PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or attorney's file reference PG 06062WO	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International Reference No.: PCT/EP 03/13664	International filing date *(month/day/year)* 12/4/2003	Priority date *(month/day/year)* 12/14/2002
International Patent Classification (IPC) or national classification and IPC F03B 11/04		
Applicant VOITH SIEMENS HYDRO POWER GENERATION GMBH et al.		

1. This international preliminary examination report has been prepared by the authority authorized with the international preliminary examination and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, that is, sheets with descriptions, claims, and/or drawings, which have been amended and are the basis for this report, and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Guidelines under the PCT).

   These annexes consist of a total of 7 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the office action
   - II ☐ Priority
   - III ☐ No preparation of expert opinion with regard to novelty, inventive step, and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Determination with grounds under Rule 66.2 a)ii) with regard to novelty, inventive step, and industrial applicability; documents and explanations supporting such determination
   - VI ☐ Specific documents cited
   - VII ☐ Specific defects in the international application
   - VIII ☐ Specific observations on the international application

Date of submission of the petition 07/29/2004	Date of completion of this report 1/26/2005
Name and mailing address of the authority authorized with the international examination [symbol] European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Vurro, L. [symbol] European Patent Office Tel. +49 89 2399-2951

INTERNATIONAL PRELIMINARY EXAMINATION REPORT International Reference No. **PCT/EP 03/13664**

I. Basis of the report

1. With regard to the **elements** of the international application (*replacement sheets that have been furnished to the receiving office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report, because they contain no amendments (Rules 70.16 and 70.17)):*

Description, Pages

1, 2, 6, 8, 9	in the version originally filed
3, 3a, 4, 5, 7	received on 11/6/2004 with letter of 11/3/2004

Claims, No.

1-7	received on 11/6/2004 with letter of 11/3/2004

Drawings, Sheets

1/8-8/8	in the version originally filed

2. With regard to the **language**: All the elements mentioned above were available or were furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available to this Authority in the language: or were furnished in this language, which is:

   ☐ the language of the translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination is carried out on the basis of the sequence listing that is:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer-readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer-readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure content in the international application as filed has been furnished.

   ☐ The statement that the information compiled in computer-readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the elimination of the following documents:

   ☐ description, pages:

   ☐ claims, No.:

   ☐ drawings, sheet:

5. ☐ This report has been prepared without considering (some of) the amendments, since they have been considered to go beyond the disclosure content as originally filed for the reasons given in the opinion of the Authority (Rule 70.2(c)).

   (Reference is made under item 1 to replacement sheets that contain such amendments; they are attached to this report.)

6. Additional observations, if any:

V. Determination with grounds under Article 35(2) with regard to novelty, inventive step, and industrial applicability; documents and explanations supporting such determination

1. Determination

Novelty (N)	Yes:	Claims 1-7
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-7
	No:	Claims
Industrial applicability (IA)	Yes:	Claims: 1-7
	No:	Claims:

2. Documents and explanations:

   See attachment

In regard to item V
Determination with grounds under Article 35(2) relative to novelty, inventive step, and industrial applicability; documents and explanations supporting such determination

1). Closest prior art FR-A-1,162,872 (D1).

Document (D1), which is viewed as the closest prior art, discloses a water turbine with a runner which has a plurality of moving blades as well as a hub.

The water turbine according to claim 1 is distinguished from the prior art by the fact that:

- the displacement unit is expanded in the direction of flow.

2). The object of the invention is to create a water turbine of the type named initially, as is known from (D1), which permits a flow in the draft tube that is as free of swirling as possible during operation.

The solution to the object set forth is accomplished by the combination of features indicated in claim 1.

The features of claim 1 are not anticipated or made obvious in a novelty-damaging manner by the prior art named in the description and in the Search Report. As a consequence of this, it results that claim 1 fulfills the requirements of Article 33(2) and (3) PCT.

3). Advantageous configurations of the invention are described in claims 2 to 14.

4). Industrial applicability of the invention is indicated.

A further development of this concept consists of positioning a chamber, which is partially filled with water and air, around the draft tube and placing this chamber in contact with the flow by means of openings in the wall of the draft tube. In this way, the air and water flow in and out in correspondence with the pressure ratios in the draft tube flow. This solution for control of swirling is also associated with corresponding structural expense, since here, along with the additional pressure chamber, a control for the air pressure in the surrounding chamber must also be incorporated.

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The object of the invention is to indicate a draft tube for a Francis turbine which has considerable advantages when compared with the prior art. In particular, the draft tube shall minimize the effect of pressure fluctuations, such as occur due to swirling flow in the case of partial load conditions. This object is solved by a draft tube of claim 1.

The inventors have recognized that when operating a Francis turbine under partial load, a recirculation zone is formed behind the runner. The transition layer between this region and the principal flow is characterized by strong velocity gradients. Hydrodynamic instabilities of the Kelvin-Helmholtz type lead to the formation of swirling "braids", which possess a rotative component due to the overall rotation of the flow. This rotating swirling braid leads to a rotating pressure, which induces a force effect in the axial direction in the region of the elbow of the draft tube and to corresponding pressure fluctuations, which also act in the axial direction and thus in the direction of the turbine. In addition, it is possible that these axial pressure fluctuations, combined with the helically shaped swirling braid, lead to interface separations in the wall region of the elbow, which additionally reinforce the effect of pressure fluctuations operating in the axial direction. This explains the formation of pressure fluctuations in the draft tube dependent on the rotational frequency of the runner.

Another component of stochastic pressure fluctuations can arise due to the fact that local pressure regions with pressures below the vapor pressure are formed due to the helical swirling braid, which leads to the formation of cavitation bubbles. When these cavitation bubbles burst, additional voltage pulses are formed.

Grein H.: "VIBRATION PHENOMENA IN FRANCIS TURBINES: THEIR CAUSES AND PREVENTION ESCHER WYSS NEWS, ESCHER WYSS, ZURICH, CH, Vol. 54/55, No. 1, 1981, pages 37-42, XP008018462 ISSN: 0367-1402 shows a Francis turbine with a longitudinally extended displacement unit in the draft tube in the region of the hub of the runner with the features that are summarized in the preamble of claim 1.

FR-A-1,162,872 disloses a cylindrical displacement unit in the draft tube of a Francis turbine.

According to the invention, a longitudinally extended displacement unit is disposed in the draft tube. Its upstream end is found in the region of the hub of the runner.

The displacement unit can be conical and expands in the direction of flow according to the invention. It is disposed in such a way that its surface shell is surrounded by flowing water. In general, its lengthwise axis coincides with the lengthwise axis of the draft tube.

Numerous variants are possible. Thus the displacement unit can be a continuation of the hub of the runner and therefore made up in one piece with the hub. Also, however, it can be connected at a minimal distance to the hub. The distance between these two parts need only be several millimeters, for example, 1, 2, 3, 5 mm. Also, 10 to 50 mm are conceivable.

Another solution consists of making the hub longer than usual, viewed in the flow direction, for example, double or triple or even five times longer, so that it forms a part of the displacement unit. Another part then follows in the flow direction. This other part is an independent component, which is thus not made up in one piece with the lengthened hub and therefore also does not rotate.

The displacement unit involves an independent component, separated fom the hub, so that it must be attached, of course, inside the draft tube. Such an attachment can be made by rods, which run perpendicular to the flow direction and are attached in the wall of the draft tube. The rods can be disposed radially.

A particularly interesting solution can consist of the upstream end of the displacement unit being mounted on the hub of the runner, so that the displacement unit can be additionally stabilized in position thereby.

The invention can be applied in both straight as well as curved draft tubes. In the case of curved draft tubes, there results an additional mounting possibility: attaching the displacement unit in the curvature region on the draft tube or on its foundation part.

The invention as well as the prior art will be explained in more detail below on the basis of the drawing. Here:

Figure 1 shows a Francis turbine in an axial section

Figure 2 shows a numerical flow simulation of the formation of a swirling braid

Figure 3 shows the classical structural form of the draft tube diffuser

Figures 3a and 3b show a curved draft tube diffuser with a first embodiment of a displacement unit

Figure 4 shows a curved draft tube diffuser with a second embodiment of the displacement unit.

Figure 5 shows a straight draft tube diffuser with another embodiment of a displacement unit, which does not have, however, an expansion according to the invention.

Figure 6 shows a curved draft tube diffuser with a displacement unit similar to the one shown according to Figures 3a and 3b.

Figure 7 shows a curved draft tube diffuser with a displacement unit similar to the one shown according to Figures 4a and 4b.

Figure 8 shows a curved draft tube diffuser with a displacement unit, which is attached only to the draft tube elbow.

The Francis turbine shown in Figure 1 is constructed as follows:

Figures 3a and 3b represent the structural form of the upper part of the draft tube of the diffuser in classical construction. Typical is the radially symmetric shaping with a circular cross section of a straight diffuser axis, which is guided in correspondence with the runner axis.

The modification of the design of the diffuser according to the invention is shown in Figure 4. Here, the cross section is not of circular shape The axis of the diffuser is inclined or displaced relative to the axis of the runner. This axis is also curved. The symmetry-breaking features are limited only to the inlet region of the draft tube. This segment, which is denoted the diffuser, terminates with the transition to the elbow, by which the runout flow is deflected from the vertical to the horizontal direction.

[The following paragraph "Figure 5....frequency" is deleted:]
[Figure 5 shows the pressure fluctuations on the time scale. The pressure fluctuations for the classical structural form of the diffuser in conical configuration are visible for comparison with the asymmetric structural form according to the invention. It can be seen that the amplitude of the pressure fluctuations is reduced for the asymmetric structural form when compared with that of the symmetric form. Both vibration curves show the vibrations synchronous with the rotational frequency of the runner as well as an additional overlapping by stochastic vibrations or vibrations of higher frequency, which are harmonics of the basic frequency.]

The draft tube diffuser which is shown is assigned to a Kaplan turbine. Only the hub 1.3 of its runner is shown. A displacement unit 5 according to the invention in turn directly terminates at hub 1.3, by its upstream end surface 5.1. The distance can be smaller than 1 mm. It can also amount to several millimeters, for example, 1 to 5 mm. Also, 10 to 20 mm are conceivable.

Patent Claims

1. A water turbine or pump or pump turbine with a runner (1.1), which has a plurality of rotor blades as well as a hub (1.3);

1.2 with a housing, which has a distributor for regulating the flow into the runner (1.1);

1.3 with a draft tube (4) for guiding the water flowing out from the runner (1.1), which has an inlet diffuser;

1.4 a longitudinally extended displacement unit (5) is disposed in the draft tube (4);

1.5 the upstream end of the displacement unit (5) is found in the region of the hub (1.3) of the runner (1)

1.6 is hereby characterized in that the displacement unit (5) is expanded in the direction of flow.

2. The turbine or pump according to claim 1, further characterized in that the distance between the hub (1.3) of the runner (1) and the upstream end (5.1) of the displacement unit amounts to between 0.5 and 50 mm.

3. The turbine or pump according to claim 1 or 2, further characterized in that the displacement unit (5) is supported by rods (6.1, 6.2, 6.3) on draft tube (4).

4. The pump or turbine according to one of claims 1 to 3, further characterized in that the displacement unit (5) is supported on the hub (1.3) of the runner.

5. The pump or turbine according to one of claims 1 to 4, further characterized in that the displacement unit (5) is made up in one piece with the hub (1.3) of the runner (1) and rotates with the latter.

6. The turbine or pump according to one of claims 1 to 3, further characterized in that the draft tube (4) runs in a straight line.

7. The pump or turbine according to one of claims 1 to 5, further characterized in that the draft tube (4) is curved.